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THE QUARTZITE TONGUE AT REPUBLIC, MICHIGAN.

I.

On Major Brooks' geological and topographical map of Republic Mountain and vicinity, Plate VI. of the Atlas of the Geological Survey of Michigan, 1873, a tongue of the upper quartzite (his formation, XIV.) is correctly represented as forking from the main mass of the same rock, and running northwest along the top of the Republic bluff, a thin wedge of the underlying specular jasper (his formation, XIII.) being interposed between them.

No explanation of this singular occurrence was given by Brooks in the text of the Michigan report.

Dr. M. E. Wadsworth[1] in 1880, as the result of personal examination, concluded that the supposed quartzite tongue was really a granite dike, intruding the jasper.

In consequence of later studies[2] by himself and his assistants, Dr. Wadsworth has recently decided that his former determination of the tongue as a dike of granite was erroneous, and that it is in fact quartzite. In this latest publication he endeavors to explain the peculiar relations by the assumption that the interposed wedge of specular jasper does not belong to the lower series, but to the upper, and was deposited later than the quartzite tongue.

In the autumn of 1891, in the course of extended work on the surface and underground at Republic, I studied this question in some detail, and concluded that the phenomena were due entirely to faulting.

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[1] Notes on the Geology of the Iron and Copper Districts of Lake Superior, 1880, pp. 34-35.

[2] Report of the State Board of Geological Survey, Lansing, 1893, pp. 129-130.

II.

For the purposes of this article it is unnecessary to give a detailed description of the Republic rocks, as their character is sufficiently indicated by the names attached to the several formations in the table below, which shows, with some slight modifications, the divisions, the order of succession, and the nomenclature as determined and used by Brooks, Wadsworth, and the United States geologists, respectively.

I. Brooks.	II. Wadsworth.	III. U. S. Geologists.
Huronian	*Holyoke Formation*	*Upper Marquette Series*
Quartzite XIV.	Quartzite	Quartzite
	Unconformity	Unconformity
Ferruginous Jasper, XIII.	Republic Formation	*Lower Marquette Series*
Specular and Magnetic Ore Formations XII.		Specular Jasper
Magnetic Siliceous Schist X., VIII., and VI.		Magnetite-Actinolite-Schist
Quartzite V.		Quartzite and Conglomerate
Unconformity	Unconformity	Unconformity
Laurentian	Cascade Formation	Archean

I have omitted from column I., the succession according to Brooks, the diorites VII., IX., and XI., which are now known to be later intrusive sheets and dikes. That Brooks should have divided the ferruginous rocks between the quartzites V. and XIV. into what we now think an unnecessary number of formations, is easily understood, when it is remembered that his classification was a provisional one for field use, which the exigencies of hurried publication forced him to retain in his final report.

In column III. I have made two divisions of the ferruginous rocks. These are sharply separated in aspect, and in the western part of the Marquette district at least, each has its own place in the stratigraphical column. The specular jasper when present, always overlies the magnetite-actinolite-schists. No theory of difference in origin is implied, and the distinction is entirely one of convenience.

Dr. Wadsworth has not, I believe, published a detailed section of the rocks at Republic.

III.

All the rocks of the Upper and Lower Marquette series have been closely folded in the Republic area into a syncline, about seven miles long, the axis of which runs about northwest and southeast. The present fold for most of its length is sunk deeply into the Archean, the axis being practically horizontal. South of Smith's Bay, however, the axis rises with a pitch of nearly 45°, the several formations swing around successively in horseshoe form through an angle of 180°, from the northeastern to the southwestern side, and the fold, so far as it affects the bedded rocks, abruptly terminates. Through the greater part of the length of the trough the rocks on the two sides of the axial plane have been squeezed nearly into parallelism. On the eastern side, few of the many surface observations show in the upper quartzite a dip less than 80°, which is the average to a depth of more than 900 feet in No. 8 shaft. On the western side the dips are somewhat lower, but will average nearly 80°.

The formations in the unconformably underlying Lower Marquette series on the eastern side of the trough dip at uniformly higher angles, and stand either vertical, or show a slightly overturned dip towards the east. There is then a pretty constant upward convergence of the two series along the contact, averaging perhaps 15°.

The distance in which the turn is made at the southeast end of the trough, or at the bottom as it really is, is relatively very short. The radius of the generalized curve into which the

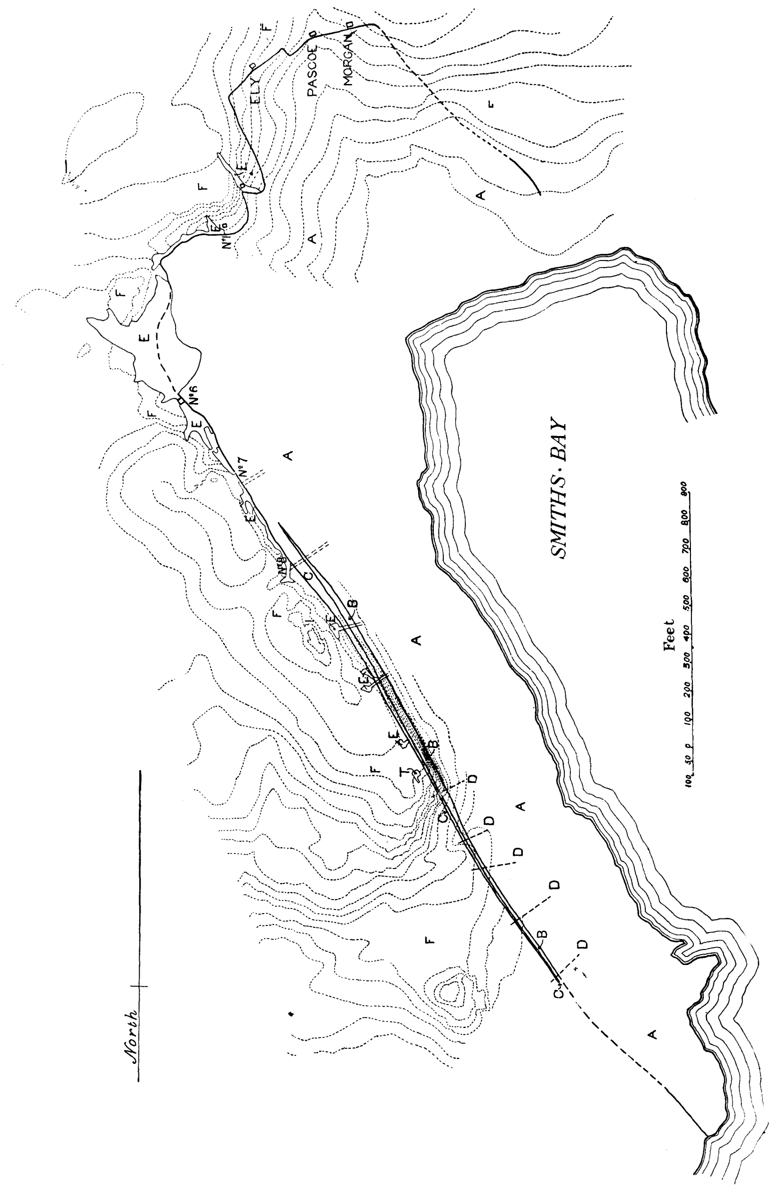

FIG. 1.—The Vicinity of the Republic Mine. A, A = Area underlaid by the Upper Marquette quartzite. B, B = Jasper Wedge. C, C = Quartzite Tongue. D, D = Diamond-drill holes. E, E = Open pits. F, F = Area occupied by the Lower Marquette Jasper. T = Thompson pit. Contours (from Brooks) at ten-foot intervals. The heavy black line is the outcrop of the base of the Upper Marquette Series. When dotted it is covered, or not precisely determinable.

base of the upper quartzite has been thrown, can be very little greater than the thickness of that formation. Field study shows clearly that the neutral surface of the folded material lay below the base of the upper quartzite, and included a considerable portion of the actinolite-schists. This is proved by the severely contorted condition (showing compression) of the thinly bedded jaspers, and by the same structure on a larger scale in the more heavily bedded quartzite. The crowding of the rocks above the neutral surface into a constricted space has resulted in the formation of three important synclines, separated by two anticlines, all subordinate to the main fold. The most eastern of the synclines occurs at the great open pit of the Republic mine; the middle, in the ground opened by the Morgan, Pascoe and Ely shafts; the westernmost in the neighborhood of the Swamp shaft[1] (Fig. 1). These larger subordinate folds are accompanied by a multitude of smaller anticlines and synclines, of various dimensions. They are smaller, more numerous, and more closely compressed in the iron-bearing member than in the overlying quartzite.

The upper quartzite, which is a massive and heavily bedded rock, yielded to the compression by differential movements of one bed over another, and doubtless also by thickening. The effects of the movement of bed on bed are strikingly shown at numerous points in the horseshoe, perhaps particularly well in the small open pit east of the Ely shaft. Here the individual quartzite layers, from one foot upwards in thickness are separated by parallel selvages of ground-up quartzitic material, varying in thickness usually from two to four inches. In the case of one, the measured thickness is eleven inches. These selvages, known locally as a variety of "soap-rock," show frequently a vertical pressure-cleavage.

It is certain, then, that the original sheet of sediments, which varied in character from thinly leaved jaspers below to heavily bedded quartzites above, and aggregated, for the area under discussion, upwards of half a mile in thickness, has been bent back upon itself, and that the neutral surface of division between the portion above, that was subjected to compression, and the portion below, that underwent tension, lay well beneath the heavily bedded quartzite. The part of the sheet above the neutral surface was confined within a progressively narrowing space, to which it had to accommodate itself by thickening the beds, by plicating them, and also by relative movement of each bed on that below it. That the accommodation thus necessitated by the mechanical conditions actually did take the form of slipping along bedding planes, is, in the case of the quartzite, clearly shown.

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[1] The Swamp shaft falls outside of the limits of Figure 1.

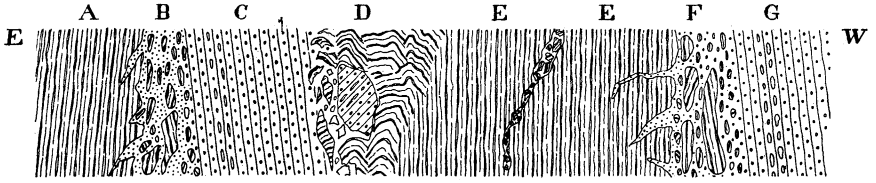

FIG. 2.—Section north of the Thompson Pit. A = Lower Marquette Jasper. B = Conglomerate. C = Quartzite tongue. D = Breccia. E = Jasper Wedge. F = Conglomerate. G = Quartzite. One inch = 20 feet.

IV.

I will now consider the quartzite tongue. The best exposures of the conglomerate at the base of the upper quartzite tongue, the included jasper wedge, and the main mass of jasper, including all contacts, may be seen on the natural cross-section afforded by the breaking down of Republic Mountain north of the Thompson pit. This section is represented in Figure 2, and a sketch plan of the outcrops is given in Figure 3. The conglomerate at the base of the main mass of quartzite is exposed on the steep western face of the bluff, from its north end almost to No. 8 shaft. It holds pebbles of jasper, of banded jasper and ore, of ore, and of quartz, which last with ferruginous matter forms the cement. The jasper inclusions are often large and angular, and in many cases it is difficult to see that they are completely detached from the main jasper body of the tongue. The conglomerate cement, which is largely made up of grains of blue quartz, fills cracks in the underlying aspe wedge, often in directions transverse to the banding (Fig. 4). Some of these cracks may be traced for several feet back from the contact. In many places the general course of the contact cuts the banding of the jasper of the wedge at a considerable angle. Altogether the conglomerate is unmistakably basal, and was clearly laid down upon an irregularly eroded surface.

From this contact for about sixteen feet to the east the jasper wedge comes in. The great mass of this rock cannot be distinguished, either by the eye or under the microscope, from the specular jasper of the Lower Marquette iron-formation. It is very rich in iron ore, the jasper bands often showing the tendency to break up into oval-shaped units that indicates an advanced stage towards concentration. Occasionally, however, within the solid body of the jasper, small patches of quartzite may be observed, which occur singly, or several together along the same general line. These patches are not interbanded with the jasper bands, but often cut them off squarely at their margins (Fig. 5). They recall the sand-pockets which occur similarly in the banded ore at the Mountain Iron Mine on the Mesabi range.[1] Here, doubtless, as there, the sand has been introduced from above, at a time subsequent to the development of the banded structure.

With the exception of these rare quartzite pockets the jasper wedge contains no foreign fragmental material. Through it, however, run several fault lines, which are indicated by narrow breccias, the materials of which are entirely derived from the jasper itself, and by displacement of the jasper bands at the walls. Some of these breccias run nearly parallel with the banding, while others cut across it at considerable angles.

The jasper wedge terminates to the east in a very distinct fault breccia some five feet in width, at its widest point north of the Thompson pit. This breccia consists of large angular pieces of jasper (one measured one by three feet), of quartzite, of quartz and of iron ore, and many pebble-like forms of all these, surrounded by more or less ferruginous, chloritic and siliceous cement, in which many grains of blue quartz occur. The jasper wedge is not separated from the breccia by any sharp line of division. The layers, which in the solid body of the wedge stand nearly vertical, become contorted near the breccia and bend towards it, the convex side of the little arches being upward on vertical sections and towards the south on the horizontal exposures (Figs. 2 and 3). This indicates that the material west of the fault, towards the interior of the trough moved relatively upwards, and had also a southerly horizontal component.

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[1] Compare Bulletin No. X., Minnesota Geological Survey, p. 205, Fig. 20.

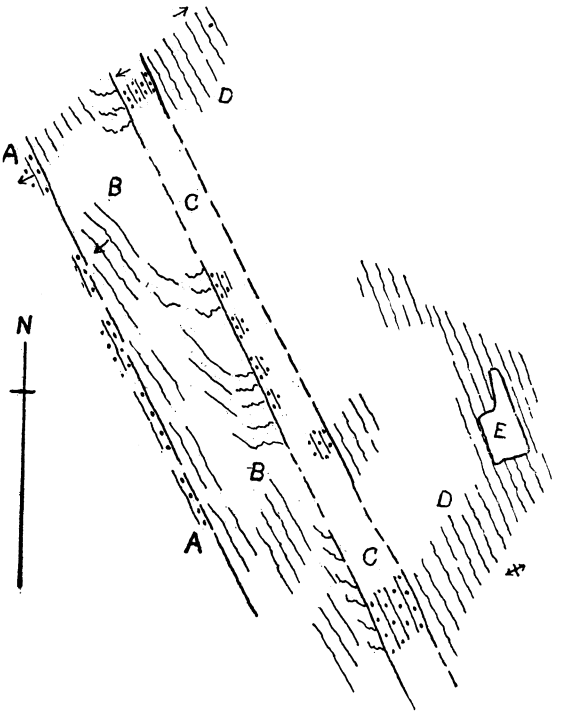

FIG. 3.—Sketch plan of the outcrops in the vicinity of the Thompson Pit. A, A = Conglomerate at the base of the main mass of the Upper Marquette Quartzite. B, B = Jasper Wedge. C, C = Quartzite tongue. D, D = Lower Marquette Jasper. E = Thompson Pit. One inch = 50 feet.

Next east of this breccia about six feet of westerly dipping quartzite comes in, constituting the quartzite tongue. South of the Thompson pit this quartzite steadily increases in thickness, and in about 300 feet attains a width of twenty-five feet. The quartzite shows the plainest marks of its sedimentary origin, and it is almost incredible that any other could have been attributed to it. It contains thin layers of conglomerate that may be followed for considerable distances. These layers are composed of nicely rounded pebbles of jasper, of specular and magnetic ore and of quartz, as well as of larger flat slabs of banded jasper. Where the quartzite becomes thicker, a little north of No. 8 shaft, the conglomerate layers in the upper portion hold a few pebbles of magnetite-actinolite-schist. In the bedding planes the pebbles have a roughly parallel inclination of 30–40° to the north, which is nearly the general pitch of the trough. A system of parallel normal joints having the same inclination also affects the quartzite as well as the jasper, and seems to have had some influence in localizing ore-concentration, since the small body at the scram immediately north of No. 8 rests upon one of them.

The quartzite tongue is also in places gashed with a parallel system of narrow quartz veins which dip south about 40°, and so are nearly normal to the pitch. These are confined to the massive quartzite, and stop short at the conglomerate layers in it, nor do they extend into the jasper wedge above or into the main jasper body below. It may be that they represent open spaces where the massive quartzite was pulled apart, possibly at existing joints, by the drag of the upper members along the fault.

Below the quartzite on the line of section follow three or four feet of conglomerate entirely similar to the conglomerate which overlies the jasper wedge, and having identical unconformable relations with the specular jasper of the Lower Marquette series, which continues in an unbroken body to the east.

The significant facts along this section (and they are equally evident at many points south), which seem clearly fatal to the idea that the jasper wedge is an interbedded member of the upper series are these: (1) It is not interbedded. (2) The main body of Upper Marquette quartzite to the west is as clearly separated from the jasper wedge by an erosion interval as the quartzite tongue is from the main body of Lower Marquette jasper upon which it rests. The jasper wedge cannot belong to the upper series unless there are two upper series. (3) The jasper of the wedge is not a fragmental rock, and no contemporaneous fragmental material has been recognized in it. It disappears a short distance south of No. 8 tunnel, and the two quartzites come together. If it were a member of the upper series, it must have been laid down at the same time that a rather coarse fragmental rock was being deposited a few hundred yards away, in which case it is hardly conceivable that clastic material should not have been largely included in it.

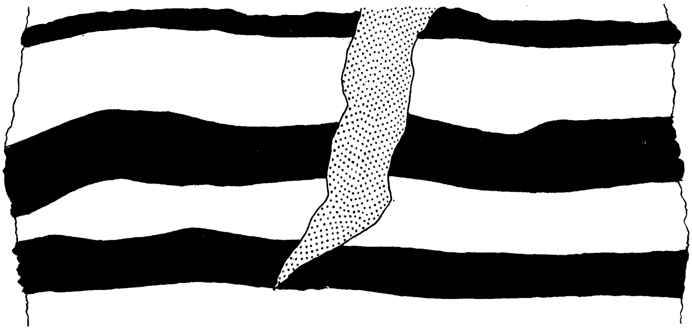

FIG. 4.—Plan showing quartzite filling a crack in the Jasper Wedge. The black bands are specular hematite; the uncolored are red Jasper. The locality is ten feet south of the suspended ladder. About one-sixth natural scale.

V.

While the relations of the quartzite tongue are correctly represented on Brooks' map, the better surface exposures of the present day, and the large amount of exploration done by the Republic Company, enable its position now to be fixed with much greater precision. Several diamond-drill holes north of the Thompson pit have shown that it extends 500 to 600 feet north of the point where it terminates on Brooks' map. It becomes steadily narrower, and as it does not appear at the Kingston and Kloman exposures on the west side of the river, there can be little doubt that it gradually dies out, and that the jasper wedge finally merges into the main body of specular jasper (Fig. 1).

Therefore, the facts to be explained appear to be these: A quartzite tongue branches in the south from the main mass of similar quartzite, and after continuing substantially parallel with it for a long distance, finally tapers to a point in the north in a mass of specular jasper. The quartzite tongue includes between itself and the main quartzite mass, an exactly similar jasper tongue which starts in the north from the mass of specular jasper, and tapers to a point in the south in quartzite, the two tongues interlocking. The quartzite in each case, in the tongue and in the main mass, has similar and unusual relations (those marking a time-break) with the jasper of the tongue and of the main mass. And between the jasper wedge and the quartzite tongue extensive faulting has taken place.

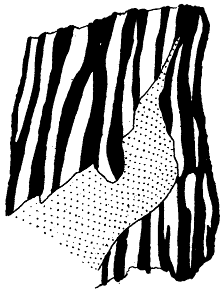

FIG. 5.—Elevation showing part of a quartzite "pocket" in the interior of the Jasper Wedge. The black bands are specular hematite; the uncolored are red Jasper. The locality is about 100 feet northwest of the Thompson Pit. About one-twelfth of the natural scale.

These facts point towards if they do not demonstrate the identity in age of the two jaspers, and of the two quartzites, and indicate that their present relations are due to faulting.

Recurring now to the mechanical conditions which affected the rocks during the folding, we have seen that the material above the neutral surface yielded to the compression, in part, by slipping along the bedding planes. If for any reason such movement could take place more easily along any one surface, the neighboring surfaces would be relieved, and one of maximum movement would result. It is readily conceivable that in the same way one local maximum might relieve several neighboring maxima, and so a large amount of movement might be accumulated along a single surface. A maximum movement, starting in the specular jasper would, on account of the slight upward convergence of dip, necessarily tend to cut across the quartzite at the contact. The quartzite might be traversed until a surface of maximum movement in it was reached, which would then be followed. The result would be a fault, along which the material on the side towards the interior of the trough would be displaced relatively upwards, and which, in the direction of the strike, might easily pass from one rock to the other more than once. The wedge of specular jasper included between the surface of movement and the contact surface would move relatively upward with the main body of quartzite, while the corresponding wedge of quartzite above the line along which the contact surface was traversed would remain relatively at rest with the main mass of jasper.

A break formed under such conditions, accompanied by displacement sufficient to bring these two wedges together, and followed by sufficient denudation, would result in the surface relations that may now be observed on Republic Mountain.

HENRY LLOYD SMYTH.

CAMBRIDGE, MASS.